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(54) [Document Name] METHOD OF FABRICATING NITRIDE SEMICONDUCTOR ELEMENT

(57) [Abstract]

[Problem] To especially provide a method of fabricating a nitride semiconductor element that enables separation of nitride semiconductor elements formed on a substrate with high yield, which is related to a method of fabricating a light-emitting diode or a laser diode capable of emitting ultraviolet to orange light in addition to a group III-V semiconductor element that can be driven even at high temperatures.

[Means for solving the problem] A method of fabricating a nitride semiconductor element (110) that splits a semiconductor wafer (100) having a nitride semiconductor (102) formed on a substrate (101) into nitride semiconductor elements (110), comprising, in particular, a step of radiating a laser beam, through the semiconductor wafer (100) from the side of a first main surface (111) and/or a second main surface (121) of the semiconductor wafer (100) that comprises the first and second main surfaces, to form a scribe line (103) at a focal point formed at least on the side of the second main surface (121) of the substrate (101) and/or the side of the first main surface (111) of the substrate (101), and a step of separating the semiconductor wafer along the scribe line.

[Claims]

[Claim 1] A method of fabricating a nitride semiconductor element (110) that splits a semiconductor wafer (100)

having a nitride semiconductor (102) formed on a substrate (101) into nitride semiconductor elements (110), characterized by comprising a step of radiating a laser beam, through the semiconductor wafer (100) from the side of a first main surface (111) and/or a second main surface (121) of the semiconductor wafer (100) that comprises the first and second main surfaces, to form a scribe line (103) at a focal point formed at least on the side of the second main surface (121) of the substrate (101) and/or the side of the first main surface (111) of the substrate (101), and a step of separating the semiconductor wafer along the scribe line.

[Claim 2] The nitride semiconductor element fabrication method according to claim 1, wherein the first main surface (111) is a nitride-semiconductor-deposition-layer side of the semiconductor wafer (100) having the nitride semiconductor (102) formed on only one side of the substrate (101), and the second main surface (121) is a substrate-exposure-surface side that lies opposite the first main surface (111) via the semiconductor wafer (100).

[Claim 3] The nitride semiconductor element fabrication method according to claim 1, wherein the scribe line is a recess (103) formed in the substrate exposure surface.

[Claim 4] The nitride semiconductor element fabrication method according to claim 1, wherein the scribe line is an affected layer (206) formed within the substrate.

[Claim 5] The nitride semiconductor element fabrication method according to claim 1, comprising a step of forming a groove section (104) substantially parallel with the scribe line by means of at least one device selected from a diamond scriber, a dicer, and a laser beam machine in the side of the first main surface (111) and/or the side of the second main surface (121) of the semiconductor wafer (100) irradiated with a laser beam.

[Claim 6] A nitride semiconductor element fabrication method that splits a semiconductor wafer (100) having a nitride semiconductor (102) formed on only one side of a substrate (101) into nitride semiconductor elements (110), characterized by comprising a step of radiating a laser beam, from the side of a first main surface (111) formed with the nitride semiconductor (102) of the semiconductor wafer (100) that comprises the first and second main surfaces, to form a scribe line (103) in the side of the second main surface (121), a step of forming, from the side of the first main surface (111), a groove section (104), that is substantially parallel with the scribe line (103) and reaches the surface of the substrate (101), and a step of separating the semiconductor wafer (100) along the scribe line (103).

[Claim 7] The nitride semiconductor element fabrication method according to claim 6, wherein the groove section (204) is formed in the surface on the side of the first main

surface (211), at which the substrate is exposed beforehand.

[Claim 8] A nitride semiconductor element fabrication method that splits a semiconductor wafer (300) having a nitride semiconductor (302) formed on only one side of a substrate (301) into nitride semiconductor elements (310), characterized by comprising a step of radiating a laser beam, from the side of a second main surface (321) that lies opposite a first main surface (311) formed with the nitride semiconductor (302) of the semiconductor wafer (300) that comprises the first and second main surfaces, to form a scribe line (308) in the side of the first main surface (311) of the substrate (301), a step of forming, from the side of the second main surface (321), a groove section (309) that does not reach the nitride semiconductor (302) substantially in parallel with the scribe line (308), and a step of separating the semiconductor wafer (300) along the scribe line (308).

[Detailed Description of the Invention]

[0001]

[Technical Field to which the Invention belongs]

The present invention relates to a method of fabricating a light-emitting diode or a laser diode capable of emitting ultraviolet to orange light in addition to a group III-V semiconductor element that can be driven even at high temperatures, and, more particularly, relates to

a method of fabricating a nitride semiconductor element formed on a substrate.

[0002]

[Prior Art]

Nowadays, semiconductor elements that utilize nitride semiconductors with a high-energy bandgap ($In_XGa_YAl_{1-X-Y}N$, $0 \leq X$, $0 \leq Y$, $X+Y \leq 1$) are being developed. As examples of devices using nitride semiconductors, light-emitting diodes capable of emitting blue, green and ultraviolet light respectively, and semiconductor lasers capable of emitting blue-violet light, have been reported. Further, a variety of semiconductor elements that are of high mechanical strength and can be driven stably even at high temperatures, and so forth, may be cited.

[0003] Normally, a semiconductor wafer laminated with semiconductor materials such as GaAs, GaP, and InGaAlAs is broken into chip shapes and used as semiconductor elements such as LED chips capable of emitting red, orange and yellow light, and so forth. Methods for breaking semiconductor wafer into chip shapes involve usage of a dicer, diamond scriber, and so forth. A dicer is a device that either fully cuts the wafer by means of the rotational movement of a disc with a diamond-edged blade, or scores a groove (half cut) wider than the width of the blade edge and then performs cutting by means of an external force. On the other hand, a diamond scriber is a device that draws extremely narrow

lines (scribe lines) in the form of cross cuts, for example, in the semiconductor wafer by means of a needle that is likewise diamond-tipped, or the like, and then performs cutting by means of an external force. Crystals with a zinc blende structure such as GaP, GaAs, and so forth, are cleaved in a '110'direction. Hence, this property can be used to separate a semiconductor wafer of GaAs, GaAlAs, GaP, or the like, into the desired shape relatively easily.

[0004] However, unlike a semiconductor element of GaAsP, GaP, InGaAlAs, or the like, which is formed on a semiconductor substrate of GaP, GaAlAs or GaAs, in the case of a semiconductor element employing a nitride semiconductor, it is difficult to form a single crystal. In order to obtain a single crystal film of a nitride semiconductor of good crystallinity, formation on a sapphire or spinel substrate takes place via a buffer layer by using MOCVD, HDVPE, or the like. A semiconductor element such as an LED chip must be formed by cutting and separating a nitride semiconductor layer formed on a sapphire substrate or similar to the desired size.

[0005] A nitride semiconductor that is deposited on sapphire, spinel, or the like, has a heteroepitaxial structure. The nitride semiconductor has a very irregular lattice constant in comparison with a sapphire substrate or similar. Further, the sapphire substrate has a single-crystal structure such as a hexagonal crystal

structure and because of this property, possesses no cleavage property. In addition, both the sapphire and nitride semiconductor are extremely hard substances with a Mohs hardness of about 9.

[0006] Therefore, cutting by means of a diamond scriber is difficult. Further, when a full cut is made by means of a dicer, cracks and chipping readily occur in the cut surfaces and hence a clean cut is not possible. In addition, depending on the case, partial detachment of the nitride semiconductor layer from the substrate sometimes occurs.

[0007] If the semiconductor wafer can be separated accurately into chip shapes without damaging the crystallinity of the nitride semiconductor, the electrical characteristics and efficiency of the semiconductor element can also be improved. Moreover, the productivity can be improved because a multiplicity of semiconductor chips can be obtained from a single semiconductor wafer.

[0008] For this reason, the nitride semiconductor wafer undergoes division to form each desired chip by combining a diamond scriber and dicer, or similar. A method of performing this division into chips is described in Japanese Patent Application Laid Open No. H8-274371 and so forth. As a specific example, a method of fabricating a nitride semiconductor element is shown in Figs. 5(A) to 5(D). A semiconductor wafer (500) having a nitride semiconductor (502) formed on a sapphire substrate (501)

is shown in Fig. 5(A). A step of forming a groove section (509) by means of a dicer (not shown) from the lower side of the sapphire substrate to a depth that does not reach the nitride semiconductor layer is shown in Fig. 5(B). A step of forming scribe lines (507) in groove sections (509) is shown in Fig. 5(C). A step of separating the semiconductor wafer (500) into chip-shaped semiconductor elements (510) after the scribing step is shown in Fig. 5(D). It is thus possible to achieve relatively clean cuts without cracks and chipping occurring in the cut surfaces.

[0009]

[Problems which the Invention is intended to solve]

However, when scribe lines and so forth are formed in only one surface of the semiconductor wafer, there is a tendency for cracks and chipping to occur readily in the other cut surface during division. Although the shape of one surface of the separated nitride semiconductor elements can be made uniform, variations arise in the shape of the other surface of the nitride semiconductor elements, and therefore cracks and chipping readily occur in the semiconductor wafer. Therefore, when the semiconductor wafer is separated, there is the problem that it is extremely difficult to perform cutting while rendering the shape of the nitride semiconductor elements completely uniform by controlling the splitting from the side of the semiconductor wafer where scribe lines are formed to the

side where no scribe lines are formed.

[0010] On the other hand, the splitting of the nitride semiconductor water can be controlled by forming scribe lines in both sides of the semiconductor wafer. However, in the formation of scribe lines in the two main surfaces of the nitride semiconductor wafer, a step in which the semiconductor wafer is turned over and re-secured while preventing the adhesion of dirt to the semiconductor wafer, and so forth, is required and hence mass-producibility is very poor. Moreover, because a semiconductor wafer having a nitride semiconductor formed on a sapphire substrate is very hard, there are frequent cases of wear and deterioration of the blade edge of the cutter of the diamond scriber, which generates fabrication costs arising from variations in the processing accuracy, and from exchanging the blade edge. In addition, when scribe lines are formed by means of a diamond scriber, the weighting of the diamond scriber must be changed in accordance with the wear of the blade edge. Further, in order to form scribe lines by means of a diamond scriber, the diamond blade edge must make contact at the appropriate angle in each case, which means there is the problem that mass-producibility is very poor.

[0011] Nowadays, at a time when the accurate formation of smaller nitride semiconductor elements with favorable mass-producibility is desirable, the abovementioned cutting methods are unsatisfactory and there is a demand

for superior methods for fabricating nitride semiconductor elements.

[0012] More particularly, if the semiconductor wafer can be separated correctly into chip shapes without damaging the crystallinity of the nitride semiconductor, the electrical characteristics, efficiency, and so forth, of the semiconductor element can be improved. Moreover, productivity is also improved because a multiplicity of nitride semiconductor elements can be obtained from a single wafer.

[0013] Therefore, the present invention further reduces the generation of cracks and chipping in the cut surfaces when a nitride semiconductor wafer is separated into chip shapes. Further, it is an object of the present invention to provide a fabrication method that forms, with favorable mass-producibility, nitride semiconductor elements that are separated into the desired size and shape with a high yield without damaging the crystallinity of the nitride semiconductor.

[0014]

[Means for Resolving the Problem]

The present invention is a method of fabricating a nitride semiconductor element (110) that splits a semiconductor wafer (100) having a nitride semiconductor (102) formed on a substrate (101) into nitride semiconductor elements (110). More particularly, the

nitride semiconductor fabrication method comprises a step of radiating a laser beam, through the semiconductor wafer (100) from the side of a first main surface (111) and/or a second main surface (121) of the semiconductor wafer (100) that comprises the first and second main surfaces, to form a scribe line (103) at a focal point formed at least on the side of the second main surface (121) of the substrate (101) and/or the side of the first main surface (111) of the substrate (101), and a step of separating the semiconductor wafer along the scribe line.

[0015] In the nitride semiconductor element fabrication method according to claim 2 of the present invention, the first main surface (111) is the nitride-semiconductor-deposition-layer side of the semiconductor wafer (100) having the nitride semiconductor (102) formed on only one side on the substrate (101), and the second main surface (121) is a substrate-exposure-surface side that lies opposite the first main surface (111) via the semiconductor wafer (100).

[0016] In the nitride semiconductor element fabrication method according to claim 3 of the present invention, the scribe line is a recess (103) formed in the substrate exposure surface.

[0017] In the nitride semiconductor element fabrication method according to claim 4 of the present invention, scribe lines are an affected layer (206) formed within the

substrate.

[0018] The nitride semiconductor element fabrication method according to claim 5 of the present invention comprises a step of forming a groove section (104) substantially parallel with the scribe line by means of at least one device selected from a diamond scriber, a dicer, and a laser beam machine in the side of the first main surface (111) and/or the side of the second main surface (121) of the semiconductor wafer (100) irradiated with a laser beam.

[0019] The nitride semiconductor element fabrication method according to claim 6 of the present invention is a nitride semiconductor element fabrication method that splits a semiconductor wafer (100) having a nitride semiconductor (102) formed on only one side of a substrate (101) into nitride semiconductor elements (110), comprising a step of radiating a laser beam, from the side of a first main surface (111) formed with the nitride semiconductor (102) of the semiconductor wafer (100) that comprises the first and second main surfaces, to form a scribe line (103) in the side of the second main surface (121), a step of forming, from the side of the first main surface (111), a groove section (104), that is substantially parallel with the scribe line (103) and reaches the surface of the substrate (101), and a step of separating the semiconductor wafer (100) along the scribe

line (103).

[0020] In the nitride semiconductor element fabrication method according to claim 7 of the present invention, the groove section (204) is formed in the surface on the side of the first main surface (211), at which the substrate is exposed beforehand.

[0021] The nitride semiconductor element fabrication method according to claim 8 of the present invention is a nitride semiconductor element fabrication method that splits a semiconductor wafer (300) having a nitride semiconductor (302) formed on only one side of a substrate (301) into nitride semiconductor elements (310), comprising a step of radiating a laser beam, from the side of a second main surface (321) that lies opposite a first main surface (311) formed with the nitride semiconductor (302) of the semiconductor wafer (300) that comprises the first and second main surfaces, to form a scribe line (308) in the side of the first main surface (311) of the substrate (301), a step of forming, from the side of the second main surface (321), a groove section (309) that does not reach the nitride semiconductor (302) substantially in parallel with the scribe line (308), and a step of separating the semiconductor wafer (300) along the scribe line (308).

[Embodiments of the Invention]

As a result of a variety of experiments, the present inventors arrived at the present invention by discovering

that, when a nitride semiconductor element is fabricated, it is possible to fabricate a nitride semiconductor element with superior mass-producibility without damaging the semiconductor characteristics by radiating a laser beam from a specified direction onto a specified location on the semiconductor wafer.

[0022] That is, according to the method of the present invention, scribe lines, which form a guide for the division into nitride semiconductor elements, can be formed at optional points other than on the laser radiation side by transmitting [a laser beam] through the nitride semiconductor wafer without damaging the nitride semiconductor layer. More particularly, both sides of the semiconductor wafer can be processed relatively simply without subjecting the nitride semiconductor element to adverse effects from the same side. The fabrication method of the present invention will be described in detail hereinbelow.

[0023] For the semiconductor wafer, a nitride semiconductor layer with an LD (laser diode) constitution is formed on a spinel substrate. More specifically, laminated on the spinel substrate are a GaN buffer layer, an n-type GaN contact layer, an n-type AlGaN cladding layer, an n-type GaN light guide layer, an InGaN active layer, which is a multiquantum well structure doped with Si and in which the In composition is changed, a p-type AlGaN

capping layer, a p-type GaN light guide layer, a p-type AlGaN cladding layer and p-type GaN contact layer. A CO_2 laser beam is radiated from the spinel substrate of the semiconductor wafer to form an affected layer as scribe lines at the interface between the nitride semiconductor layer and the spinel substrate. Grooves are then formed in the spinel substrate by means of a dicer, substantially in parallel with the scribe lines. Nitride semiconductor elements are formed by applying pressure along the grooves by means of a roller. All the edges of the nitride semiconductor elements thus separated are formed cleanly. The apparatus and so forth used in the process of the present invention will be described in detail hereinbelow.

[0024] (Nitride semiconductor wafers 100, 200, 300, 400)

The nitride semiconductor wafers 100, 200, 300, 400 have a nitride semiconductor 102 formed on a substrate 101. For the substrate 101 of the nitride semiconductor 102, a variety of single crystals of sapphire, spinel, silicon carbide, zinc oxide, gallium nitride, and so forth, may be cited. However, in order to form a nitride semiconductor layer of favorable crystallinity with good mass-producibility, a sapphire substrate or spinel substrate, or the like, is suitably used. The present invention works especially effectively because the sapphire substrate or similar has no cleavage property and is extremely hard. The nitride semiconductor may be formed

on one side of the substrate or on both sides thereof.

[0025] The nitride semiconductor ($In_XGa_YAl_{1-X-Y}N$, $0 \leq X$, $0 \leq Y$, $X+Y \leq 1$) can be formed in a variety of ways by means of MOCVD, HVPE, and so forth. The nitride semiconductor can be used as a semiconductor element by forming a PN junction, PIN junction, or MIS junction in the nitride semiconductor. A variety of junctions such as a homo junction, hetero junction, and double hetero junction can also be selected for the structure of the semiconductor. Furthermore, the semiconductor layer can also be a single quantum well structure or a multiquantum well structure rendered as a thin film permitting the generation of the quantum effect.

[0026] The nitride semiconductor has a relatively large bandgap and is thermally resistant. Therefore, the nitride semiconductor can be utilized as a variety of semiconductor elements such as light-emitting elements including a light-emitting diode that is capable of emitting light from ultraviolet to red, and a short-wavelength laser that can be used for a DVD or the like, as light-receiving elements such as a light sensor, or a solar cell with a relatively high electromotive force, or as heat-resistant transistors.

[0027] Although a variety of substrate thicknesses can be selected depending on the processing accuracy and output of the laser beam machine, when a large groove (deep groove) is formed by the laser beam, the groove sections and so

forth formed by the laser processing are preferably not formed too large from the point of view of the time taken in comparison with [processing by means of] a diamond scriber or dicer and the partial destruction caused by heating over a long period and so forth. Therefore, with mass-producibility in mind, in addition to forming the groove sections 104 in the semiconductor wafer by means of a laser, a variety of processes performed by a dicer, diamond scriber, and so forth, can be selected. Alternatively, formation can be implemented by means of a combination of such processes.

[0028] When a sapphire substrate laminated with a nitride semiconductor is separated, the thickness of the thinnest division section of the nitride semiconductor wafer is preferably 100 „m or less in order to achieve cutting of the cut edges with favorable mass-producibility. When the thickness is 100 „m or less, chipping, cracks, and so forth are small and division can be performed relatively easily. Although there is no particular lower-limit value for the substrate thickness, when the substrate is quite thin, the semiconductor wafer itself splits readily and mass-producibility is poor. The thickness is therefore preferably 30 „m or more. Further, in cases where the nitride semiconductor layer contains a thin film with a single quantum well structure, multiquantum well structure, or similar, the nitride semiconductor layer, which is

irradiated with a laser beam beforehand with the object of preventing damage to the semiconductor junction and semiconductor layer caused by laser radiation, can also be removed in advance by etching or the like. Various dry etching or wet etching processes can be used for the etching.

[0029] In the case of a nitride semiconductor wafer for a light-emitting diode, the substrate normally has a thickness from 300 „m to 500 „m, and a nitride semiconductor layer with a pn junction has a thickness of several „m to several tens of „m. Hence, most of the semiconductor wafer is taken up by the thickness of the substrate. The thickness of the substrate can be made thinner by polishing in order to simplify the laser processing. This polishing may be used to thin the semiconductor wafer after the nitride semiconductor has been formed or the nitride semiconductor can be formed on a substrate that has been polished thin.

[0030] Further, it is thought that the nitride semiconductor wafer irradiated with the laser beam becomes the recesses 103, 403 or the affected layer 206, 308, which is an assembly of microscopic microcracks, along which the focal-point radiation portion selectively flies. Further, with the total film thickness of the semiconductor wafer to be processed and separated serving as a reference, 'first main surface side' and 'second main surface side'

refer to optional positions oriented toward the first main surface or second main surface from half the total film thickness. Therefore, this may be on the surface of the semiconductor wafer or within the semiconductor wafer. In addition, the present invention may laser-process the center of the total film thickness of the semiconductor wafer in addition to laser-processing the first main surface side and/or second main surface side.

[0031] (Laser beam machine) The laser beam machine employed by the present invention may be one that is capable of forming grooves permitting division of the nitride semiconductor wafer, an affected layer, and so forth. More specifically, a CO_2 laser, YAG laser, excimer laser, and so forth, is suitably used.

[0032] The laser beam radiated by the laser beam machine is one that permits a variety of adjustments to the focal point as desired by means of a lens optical system or similar. Therefore, grooves, affected layers, and so forth, can be formed, without damaging the nitride semiconductor, at an optional focal point on the semiconductor wafer by means of laser radiation from the same direction. Further, the laser radiation surface can also be adjusted to the desired shape such as a perfect circle shape, an elliptical shape, or a rectangular shape by allowing [the laser beam] passage through a filter, and so forth.

[0033] For the formation of scribe lines by means of a laser

beam machine, the laser radiation device itself may be moved. Alternatively, the scribe lines can be formed by scanning the radiated laser beam alone by means of a mirror or the like. In addition, desired scribe lines can also be formed by driving a stage that holds the semiconductor wafer in a variety of ways such as up and down, from side to side or through 90 degrees. It is understood that, although this is described in detail in the embodiments of the present invention hereinbelow, the present invention is not limited to or by these embodiments alone.

[0034]

[Embodiment] (First Embodiment) A nitride semiconductor wafer is formed by laminating a nitride semiconductor by using MOCVD onto a substrate of washed sapphire with a thickness of 200 „m. The nitride semiconductor is deposited as a multilayered film capable of serving as a light-emitting element following the splitting of the substrate. First, a buffer layer with a thickness of about 200 angstroms is formed by allowing NH_3 (ammonia) gas and TMG (trimethyl gallium) gas, which are the source gases, and hydrogen gas, which is the carrier gas, to flow at 510°C.

[0035] Next, after halting the introduction of TMG gas, the temperature of the reactor is set at 1050°C and a GaN layer with a working thickness of approximately 4 „m is formed as an n-type contact layer by allowing NH_3 (ammonia) gas,

TMG gas, SiH_4 (silane) gas, which is the dopant gas, and hydrogen gas, which is the carrier gas to flow once again.

[0036] For the active layer, once, with the carrier gas alone, the temperature of the reactor has been held at 800°C, an undoped InGaN layer approximately 3 nm thick is deposited by allowing NH_3 (ammonia) gas, TMG gas, and TMI (trimethyl indium), which are the source gases, and hydrogen gas, which is the carrier gas, to flow.

[0037] In order to form the cladding layer on the active layer, the introduction of source gases is halted and the temperature of the reactor is held at 1050°C, whereupon a GaAlN layer that is approximately 0.1 „m thick is formed as a p-type cladding layer by allowing NH_3 (ammonia) gas, TMA (trimethyl aluminum) gas, and TMG gas, which are the source gases, Cp_2Mg (cyclopentadienylmagnesium) gas, which is the dopant gas, and hydrogen gas, which is the carrier gas, to flow.

[0038] Finally, the temperature of the reactor is held at 1050 °C, and a GaN layer that is approximately 0.5 „m thick is formed as a p-type contact layer by allowing NH_3 (ammonia) gas, TMG gas, which are the source gases, Cp_2Mg gas, which is the dopant gas, and hydrogen gas, which is the carrier gas, to flow (Fig. 1(A)). (The p-type nitride semiconductor layer is annealed at 400°C or more).

The semiconductor wafer 100 thus formed is secured atop a table that is freely drivable in vertical and lateral

planar directions such that the formed nitride semiconductor 102 lies at the top. A laser beam (of wavelength 356 nm) is radiated from the side of the nitride semiconductor 102 formed on the sapphire substrate 101, the laser optical system being adjusted so that the focal point is substantially on the bottom surface of the sapphire substrate 101. By moving the stage while radiating the adjusted laser beam at 16 J/cm^2, scribe lines 103 that are approximately 4 „m deep are formed vertically and horizontally in the bottom surface of the sapphire substrate 101. When viewed from the main surface of the nitride semiconductor wafer 100, the scribe lines 103 thus formed are formed to establish a size of approximately 350 µm squared for the nitride semiconductor elements 110 to be formed subsequently (Fig. 1(B)).

[0039] Next, groove sections 104, which extend from the upper surface of the nitride semiconductor 102 to the sapphire substrate 101, are formed in the semiconductor wafer 100 means of a dicer with the nitride semiconductor wafer still secured after substituting only the laser radiation portion of the laser beam machine for a dicing saw. The groove sections 104 formed by the dicer are formed in parallel with the scribe lines 103 formed by means of laser radiation, via the semiconductor wafer 100, such that the gap between the bottom surface of the groove section 104 and the bottom surface of the side of the sapphire

substrate 101 is then substantially uniform at 100 „m (Fig. 1(C)).

[0040] A nitride semiconductor wafer can be cut and separated by allowing a load provided by a roller (not shown) to act along the scribe lines 103. A nitride semiconductor element 110 in which no chipping or cracks are present on any of the cut edges can thus be formed (Fig. 1(D)).

[0041] In the first embodiment, the scribe lines 103 are formed by means of a laser beam that is focused on the bottom surface of the sapphire substrate 101, which is the rear-surface side of the semiconductor wafer 100, and transmitted via the nitride semiconductor 102 and the sapphire substrate 101 rather than being focused on the surface side of the semiconductor wafer 100 where the nitride semiconductor 102 irradiated with the laser beam is formed.

[0042] By forming the groove sections 104, which extend from the main surface side (laser radiation side) of the semiconductor wafer 100 formed with the nitride semiconductor 102 to the sapphire substrate 101 or similar, the nitride semiconductor element 110 can be separated along the scribe lines 104 easily and accurately.

[0043] Further, because the scribe lines 103 are formed by means of a laser beam, costs arising from variations in the processing accuracy owing to wear and deterioration of a

cutter and from exchanging the blade edge, as in the case of a diamond scriber, can be reduced. Further, results similar to those achieved by processing from both sides of the semiconductor wafer are obtained by processing from only one side of the semiconductor wafer and a nitride semiconductor element 110 whose upper and rear surfaces both have a uniform shape can be fabricated, the fabrication yield is raised and shape variations can be reduced, and, especially, to the same extent, substitution can be reduced and the number of semiconductor elements yielded can be raised. In addition, because scribe lines 110 are formed in the surface of the sapphire substrate 101, scribe lines can be formed without processing waste produced by a laser beam adhering to the top of the nitride semiconductor 102.

[0044] (Second Embodiment) A semiconductor wafer, on which a plurality of island-shaped nitride semiconductor layers 205 is formed by etching a semiconductor wafer formed as per the first embodiment until the surface of the boundary with the sapphire substrate formed with groove sections is exposed from the side of the nitride semiconductor surface by means of RIE (Reactive Ion Etching), is used. Further, a mask for exposure of pn semiconductors during etching is formed and removed after the etching process. Further, electrodes 220 are formed on the pn semiconductor layers by sputtering (Fig. 2(A)).

[0045] The semiconductor wafer 200 is fixedly placed on a laser beam machine as per the first embodiment. So too in the second embodiment, the laser beam from the laser beam machine is radiated from the side of the nitride semiconductor 205 of the nitride semiconductor wafer and the laser optical system is adjusted so that the focal point is within a sapphire substrate 201 which is 20 „m from the bottom surface of the sapphire substrate. Scribe lines for the affected layer 206 are formed (Fig. 2(B)) within the substrate close to the bottom surface of the sapphire substrate by moving the stage while radiating the adjusted laser beam at 16 J/cm^2.

[0046] Next, the laser optical system (not shown) is readjusted so that the focal point is then on the upper surface (formation surface side of the nitride semiconductor) of the sapphire substrate 201 exposed by means of etching. By moving the stage while radiating the adjusted laser beam, grooves that reach the sapphire substrate are formed in the semiconductor wafer from the upper surface of the nitride-semiconductor-layer side thereof. The grooves 204 thus formed are formed substantially in parallel with the affected layer 206 via the sapphire substrate 201. Further, the grooves 204 in the sapphire substrate 201 formed by means of laser radiation are adjusted so that the gap between the bottom surface of the groove and the bottom surface of the sapphire

substrate is substantially uniform at approximately 100 μm. In addition, the laser optical system is re-adjusted so that the focal point is then on the bottom surface of the groove provided in the sapphire substrate 201. Scribe lines 207 with a depth of approximately 3 μm are formed (Fig. 2(C)) in the bottom surface of the grooves 204 provided in the exposure surface of the sapphire substrate formed with the nitride semiconductor by moving the stage while radiating the adjusted laser beam at 14 J/cm^2.

[0047] Next, by allowing a load provided by a roller to act along the grooves (scribe lines), the semiconductor wafer is cut and LED chips 210 are separated (Fig. 2(D)).

[0048] When the LED chips thus formed are supplied with electrical power, all the LED chips are capable of emitting light and barely any chipping was produced in the cut edges of the LED chips. The yield was 98% or more.

[0049] In the second embodiment, by forming scribe lines in both the surface and rear surface of the substrate by means of a laser beam from the side of one surface of the semiconductor wafer, the nitride semiconductor element can be easily separated along scribe lines even in the case of a thick nitride semiconductor wafer. Further, because the sections formed with grooves are etched as far as the sapphire substrate, the damage to the nitride semiconductor resulting from the groove formation is further reduced, meaning that the reliability of the

nitride semiconductor element following division can be improved. More particularly, when scribe lines are formed, the semiconductor wafer is secured after the focal point of the laser is within the sapphire substrate. Processing can thus be implemented without damaging the table or adhesive sheet. Further, the generation of processing waste resulting from laser radiation does not take place. Thus, nitride semiconductor elements can be formed with favorable mass-producibility as per the present invention even when all the grooves are formed by means of a dicer rather than by laser processing.

[0050] Grooves and scribe lines can be processed by means of a laser beam without making contact with the nitride semiconductor wafer. For this reason, costs arising from variations in processing accuracy due to wear and deterioration of the blade and cutter and from exchanging the blade edge can be reduced. Further, results similar to those achieved by processing from both sides of the semiconductor wafer are obtained by processing from only one side of the semiconductor wafer and a semiconductor chip with a uniform shape can be fabricated. The fabrication yield can be raised and shape variations can be reduced, and, to the same extent, substitution can be reduced and the number of semiconductor elements yielded from the nitride semiconductor wafer can be raised.

[0051] In addition, narrower grooves can be formed by also

forming grooves from the surface of the semiconductor layer by means of a laser beam. Hence, the number of chips yielded from the nitride semiconductor wafer can be raised still further.

[0052] (Third Embodiment) A semiconductor wafer 300 formed similarly to the first embodiment is provided with a mirror finish by polishing a sapphire substrate 301 beforehand to 80 „m. This semiconductor wafer is fixedly placed on the stage of the laser beam machine (Fig. 3(A)) as per the first embodiment, with the surface of the sapphire substrate 301, on which a nitride semiconductor 302 is not laminated, at the top.

[0053] In the third embodiment, a laser beam from a laser beam machine (not shown) is radiated from the side of the sapphire substrate 301 (substrate-exposure-surface side) not formed with the nitride semiconductor 302 of the nitride semiconductor wafer 300, the laser optical system being adjusted so that the focal point is at the interface between the nitride semiconductor 302 and sapphire substrate 301. Scribe lines for the affected layer 308 are formed as first scribe lines vertically and horizontally (Fig. 3(B)) close to the interface between the nitride semiconductor 302 and the sapphire substrate 301 that contacts the nitride semiconductor by radiating a laser beam while driving the stage.

[0054] Next, groove sections 309, which extend from the

bottom face side of the sapphire substrate not laminated with a nitride semiconductor but not reaching the surface of the nitride semiconductor, are formed with a blade rotational speed of 30,000 rpm and of a cutting speed of 3 mm/sec by means of a dicer with the nitride semiconductor wafer still secured by substituting the laser radiation portion of the laser beam machine alone with a dicing saw (not shown). The grooves formed by means of the dicer are provided vertically and horizontally substantially in parallel with the affected layer 308 and are formed such that the gap between the bottom surface of the groove sections 309 and the bottom surface of the sapphire substrate is substantially uniform at 50 „m. Further, the dicing saw is substituted with the laser beam machine and the focal point of the laser beam is aligned with the bottom surface of the groove sections 309 formed by means of the dicer. Second scribe lines 307 with a depth of approximately 3 „m are thus formed (Fig. 3(C)) in the bottom surface of the groove sections 309 formed in the sapphire substrate 301 by means of laser radiation.

[0055] The nitride semiconductor wafer is cut and separated by allowing a load provided by a roller (not shown) to act along the second scribe lines 307, whereby nitride semiconductor elements 310 are formed (Fig. 3(D)). There was barely any chipping of the cut edges of the nitride semiconductor elements thus formed.

[0056] The method described in the third embodiment permits separation of nitride semiconductor elements 310 easily and accurately along the scribe lines formed by means of the laser beam by separately forming groove sections 309 that extend from the side of the rear surface of the sapphire substrate 301 or similar but do not reach the nitride semiconductor 302. Therefore, a nitride semiconductor element, whose upper and rear surfaces both have a uniform shape, can be provided and the product yield can be improved. Further, the formation of the first and second scribe lines by means of laser processing can also be performed after processing with a dicer. Processing with a dicer can also be executed after the formation of the first and second scribe lines.

[0057] Because the formation of the scribe lines is performed by means of a laser beam, costs arising from variations in the processing accuracy owing to wear and deterioration of the cutter of the diamond scriber and from exchanging the blade edge can be reduced. Further, results similar to those achieved by processing from both sides of the semiconductor wafer are obtained by processing from only side of the semiconductor wafer without turning over the nitride semiconductor wafer. Semiconductor chips of uniform shape can be fabricated, and the fabrication yield can be raised and shape variations reduced, and therefore substitution can be reduced and the number of semiconductor

chips yielded from the nitride semiconductor wafer can be raised. In addition, processing waste produced by laser processing does not adhere to the surface of the nitride semiconductor.

[0058] (Fourth Embodiment) A semiconductor wafer 400, on which a plurality of island-shaped nitride semiconductors 405 are formed by etching a semiconductor wafer formed as per the first embodiment until the surface of the boundary of the sapphire substrate 401 formed with grooves is exposed from the side of the nitride semiconductor surface by means of RIE (Reactive Ion Etching), is used. Further, a mask for exposure of pn semiconductors during etching is formed and removed after the etching process. Further, electrodes 420 are formed on the pn semiconductor layers by sputtering. The sapphire substrate 401 of the semiconductor wafer 400 is provided with a mirror finish by polishing the sapphire substrate 401 to 100 „m (Fig 4(A)).

[0059] The semiconductor wafer 400 is fixedly placed on a laser beam machine (not shown) as per the first embodiment, with the sapphire substrate 401, on which no nitride semiconductor is laminated, at the top. In the fourth embodiment, the laser beam of the laser beam machine is radiated from the side of the sapphire substrate 401 not formed with the nitride semiconductor 405 of the semiconductor wafer (400), the laser optical system (not

shown) being adjusted so that the focal point is close to the surface of the surface side of the sapphire substrate (substrate is pre-exposed) laminated with the nitride semiconductor 405. First scribe lines 403 with a depth of approximately 4 „m are formed vertically and horizontally (Fig. 4(B)) in the sapphire substrate 401 by means of laser scanning.

[0060] Next, by scanning a laser beam after re-adjusting the laser optical system, groove section 409 that extend from the side of the sapphire substrate 401 but do not reach the surface of the nitride semiconductor 405 are formed in the nitride semiconductor wafer along the first scribe lines 403. By means of laser scanning after re-adjusting the laser optical system, second scribe lines with a depth of approximately 3 „m are formed in the bottom surface of the grooves (Fig. 4(C)).

[0061] The nitride semiconductor wafer is separated by allowing a load provided by a roller (not shown) to act along the scribe lines, whereby nitride semiconductor elements 410 are formed (Fig. 4(D)).

[0062] When the LED chips, which are the separated nitride semiconductor elements, are supplied with electrical power, all the LED chips are capable of emitting light, and a check of the edges thereof reveals barely any chipping or cracks. The yield was 98% or more.

[0063] Because the formation of the scribe lines is

performed by means of a laser beam, costs arising from variations in the processing accuracy owing to wear and deterioration of the cutter of the diamond scriber and from exchanging the blade edge can be reduced. Further, results similar to those achieved by processing from both sides of the semiconductor wafer are obtained by processing from only side of the nitride semiconductor wafer. Semiconductor elements of uniform shape can be fabricated, and the fabrication yield can be raised and shape variations reduced, and, to the same extent, substitution can be reduced and the number of semiconductor chips yielded from the nitride semiconductor wafer can be raised.

[0064] (Fifth Embodiment) Except for the use of an excimer laser instead of the YAG laser radiation of the first embodiment, the semiconductor wafer is separated to form LED chips as per the first embodiment. When the semiconductor wafer is separated as per the first embodiment, division is possible without turning over the semiconductor wafer. Further, all the cut edges of the LED chips thus formed are capable of light emission and have clean surfaces free of chipping and cracks.

[0065] (Comparative Example 1) Other than scribing being repeated three times by means of a diamond scriber rather than by laser processing, the semiconductor wafer is separated as per the first embodiment. The separated nitride semiconductor elements of Comparative Example 1

exhibited partial cracking. Further, the yield was approximately 84% or less due to splitting. Further, labor such as turning over the semiconductor wafer was necessary for the formation of scribe lines and grooves by means of a dicer in the two sides of the semiconductor wafer, and, hence, productivity was very poor and the production time was approximately 1.5 times longer.

[0066]

[Effects of the Invention]

According to the method of fabricating a nitride semiconductor element of the present invention, the energy can be concentrated in the neighborhood of the desired focal point by focusing the laser beam radiated by the laser source by means of a lens optical system or similar. The work processing is executed at the focal point at which the energy concentration is extremely high. More particularly, the focal point of a laser that has been transmitted by a nitride semiconductor wafer is utilized. A laser beam, which is adjusted by means of the optical system, is radiated onto a nitride semiconductor wafer, which is a part not requiring division, and processing can be freely performed on the laser radiation surface of the nitride semiconductor wafer as far as the surface on the opposite side of the semiconductor wafer without damaging the required nitride semiconductor layer.

[0067] Therefore, because the present invention uses

processing at the desired focal point following transmission [of the laser beam] by the nitride semiconductor wafer, the nitride semiconductor wafer need not be processed from both sides, and it is possible to obtain the same results as those achieved by processing from the surface and rear surface of the nitride semiconductor wafer by means of processing from only one side. It is therefore possible to further increase the yield and provide nitride semiconductor elements with small variations in shape and a fabrication method with favorable mass-producibility for the nitride semiconductor elements.

[0068]

[Brief Description of the drawings]

[Fig. 1] Fig. 1 is a schematic partial cross-sectional view of the semiconductor-wafer division method according to the first embodiment of the present invention.

[0069]

[Fig. 2] Fig. 2 is a schematic partial cross-sectional view of the semiconductor-wafer division method according to the second embodiment of the present invention.

[0070]

[Fig. 3] Fig. 3 is a schematic partial cross-sectional view of the semiconductor-wafer division method according to the third embodiment of the present invention.

[0071]

[Fig. 4] Fig. 4 is a schematic partial cross-sectional view of the semiconductor-wafer division method according to the fourth embodiment of the present invention.

[0072]

[Fig. 5] Fig. 5 is a schematic partial cross-sectional view of a nitride semiconductor-wafer cutting method, which is shown for the purpose of a comparison with the present invention.

[0073]

[Explanation of the reference symbols]

100, 200, 300, 400: semiconductor wafer

101, 201, 301, 401: substrate

102, 302: nitride semiconductor layer

103, 403: scribe lines formed in the substrate surface

104, 204: groove sections formed in the sapphire substrate from the surface of the semiconductor layer

205, 405: island-shaped nitride semiconductor layers

206: scribe lines for the affected layer formed within the substrate

207, 307, 407: scribe lines formed in the bottom surface of the groove sections

308: scribe lines formed at the boundary between the semiconductor layer and substrate

309, 409: groove sections formed in the sapphire substrate

110, 210, 310, 410: nitride semiconductor element

111, 211, 311, 411: first main surface

121, 221, 321, 421: second main surface

220, 420: electrode

500: semiconductor wafer

501: substrate

502: nitride semiconductor layer

507: scribe lines formed in the bottom surface of the groove

509: groove sections formed in the sapphire substrate

510: nitride semiconductor element

Translator's Notes

1. **マイクロ・クロック** in line 3 of [0030] should probably read **マイクロクラック** and has been rendered as such.

2. **シクロペンタジエルマグシウム** in line 5 of [0037] should probably read **シクロペンタディエニルマグネシウム** and has been rendered as such.

3. **スクライブ・ライン１０４** in the fourth line of [0042] should probably read スクライブ・ライン１０３.

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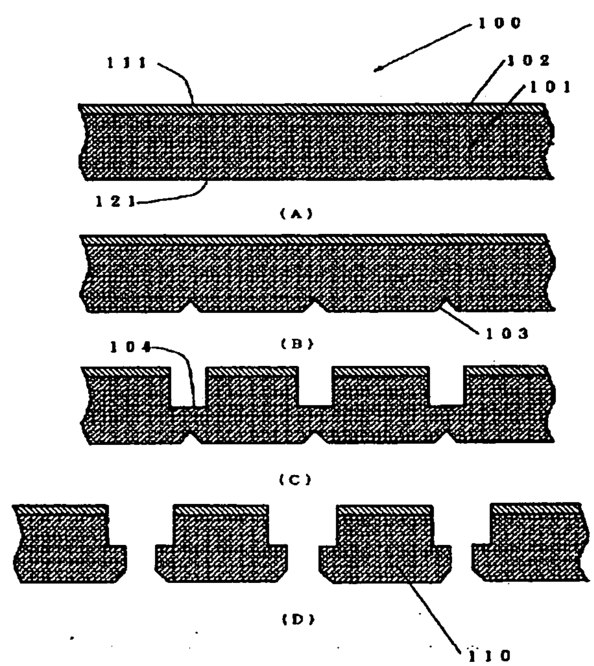
(54)【発明の名称】　窒化物半導体素子の製造方法

(57)【要約】
【課題】紫外域から橙色まで発光可能な発光ダイオードやレーザーダイオード更には、高温においても駆動可能な３－５族半導体素子の製造方法に係わり、特に、歩留まりよく基板上に形成された窒化物半導体素子を分離可能な窒化物半導体素子の製造方法を提供する。
【解決手段】基板(101)上に窒化物半導体(102)が形成された半導体ウエハー(100)を窒化物半導体素子(110)に分割する窒化物半導体素子(110)の製造方法であり、特に半導体ウエハー(100)は第１及び第２の主面を有し第１の主面(111)側及び／又は第２の主面(121)側からレーザーを半導体ウエハー(100)を介して照射し少なくとも基板(101)の第２の主面(121)側及び／又は基板(101)の第１の主面(111)側に形成された焦点にスクライブ・ライン(103)を形成する工程と、スクライブ・ラインに沿って半導体ウエハーを分離する工程とを有する。



【特許請求の範囲】

【請求項１】基板(101)上に窒化物半導体(102)が形成された半導体ウエハー(100)を窒化物半導体素子(110)に分割する窒化物半導体素子(110)の製造方法であって、
前記半導体ウエハー(100)は第１及び第２の主面を有し該第１の主面(111)側及び／又は第２の主面(121)側からレーザーを前記半導体ウエハー(100)を介して照射し少なくとも前記基板(101)の第２の主面(121)側及び／又は前記基板(101)の第１の主面(111)側に形成された焦点にスクライブ・ライン(103)を形成する工程と、
前記スクライブ・ラインに沿って半導体ウエハーを分離する工程とを有することを特徴とする窒化物半導体素子の製造方法。

【請求項２】前記第１の主面(111)は基板(101)上の一方にのみ窒化物半導体(102)が形成された半導体ウエハー(100)の窒化物半導体積層側であり、第２の主面(121)は半導体ウエハー(100)を介して第１の主面(111)と対向する基板露出面側である請求項１に記載された窒化物半導体素子の製造方法。

【請求項３】前記スクライブ・ラインは基板露出面に形成された凹部(103)である請求項１に記載された窒化物半導体素子の製造方法。

【請求項４】前記スクライブ・ラインは基板内部に形成された加工変質層(206)である請求項１に記載された窒化物半導体素子の製造方法。

【請求項５】レーザーが照射される前記半導体ウエハー(100)の第１の主面(111)側及び／又は第２の主面(121)側にダイヤモンドスクライバー、ダイサー、レーザー加工機から選択される少なくとも１種によって前記スクライブ・ラインと略平行の溝部(104)を形成する工程を有する請求項１に記載された窒化物半導体素子の製造方法。

【請求項６】基板(101)上の一方にのみ窒化物半導体(102)が形成された半導体ウエハー(100)を窒化物半導体素子(110)に分割する窒化物半導体素子の製造方法であって、
第１及び第２の主面を有する半導体ウエハー(100)の窒化物半導体(102)が形成された第１の主面(111)側からレーザーを照射して第２の主面(121)側にスクライブ・ライン(103)を形成する工程と、
前記第１の主面(111)側から前記スクライブ・ライン(103)と略平行であり基板(101)表面に達する溝部(104)を形成する工程と、
前記スクライブ・ライン(103)に沿って半導体ウエハー(100)を分離する工程とを有することを特徴とする窒化物半導体素子の製造方法。

【請求項７】前記溝部(204)は第１の主面(211)側の予め基板が露出された表面に形成される請求項６に記載された窒化物半導体素子の製造方法。

【請求項８】基板(301)上の一方にのみ窒化物半導体(302)が形成された半導体ウエハー(300)を窒化物半導体素子(310)に分割する窒化物半導体素子の製造方法であって、
第１及び第２の主面を有する半導体ウエハー(300)の窒化物半導体(302)が形成された第１の主面(311)と対向する第２の主面(321)側からレーザーを照射して基板(301)の第１の主面(311)側にスクライブ・ライン(308)を形成する工程と、
前記第２の主面(321)側から窒化物半導体(302)に達しない溝部(309)を前記スクライブ・ライン(308)と略平行に形成する工程と、
前記スクライブ・ライン(308)に沿って前記半導体ウエハー(300)を分離する工程とを有することを特徴とする窒化物半導体素子の製造方法。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は紫外域から橙色まで発光可能な発光ダイオードやレーザーダイオード、更には高温においても駆動可能な３－５族半導体素子の製造方法に係わり、特に、基板上に形成された窒化物半導体素子の製造方法に関する。

【０００２】

【従来技術】今日、高エネルギーバンドギャップを有する窒化物半導体（$In_XGa_YAl_{1-X-Y}N$、$0 \leq X$、$0 \leq Y$、$X+Y \leq 1$）を利用した半導体素子が開発されつつある。窒化物半導体を利用したデバイス例として、青色、緑色や紫外がそれぞれ発光可能な発光ダイオードや青紫光が発光可能な半導体レーザが報告されている。更には高温においても安定駆動可能且つ機械的強度が高い各種半導体素子などが挙げられる。

【０００３】通常、ＧａＡｓ、ＧａＰやＩｎＧａＡｌＡｓなどの半導体材料が積層された半導体ウエハーは、チップ状に切り出され赤色、橙色、黄色などが発光可能なＬＥＤチップなどの半導体素子として利用される。半導体ウエハーからチップ状に切り出す方法としては、ダイサー、やダイヤモンドスクライバーが用いられる。ダイサーとは刃先をダイヤモンドとする円盤の回転運動によりウエハーをフルカットするか、又は刃先巾よりも広い巾の溝を切り込んだ後（ハーフカット）、外力によりカットする装置である。一方、ダイヤモンドスクライバーとは同じく先端をダイヤモンドとする針などにより半導体ウエハーに極めて細い線（スクライブ・ライン）を例えば碁盤目状に引いた後、外力によってカットする装置である。ＧａＰやＧａＡｓ等のせん亜鉛構造の結晶は、へき開性が「１１０」方向にある。そのため、この性質を利用してＧａＡｓ、ＧａＡｌＡｓ、ＧａＰなどの半導体ウエハーを比較的簡単に所望形状に分離することができる。

【０００４】しかしながら、窒化物半導体を利用した半導体素子は、ＧａＰ、ＧａＡｌＡｓやＧａＡｓ半導体基

板上に形成させたＧａＡｓＰ、ＧａＰやＩｎＧａＡｌＡｓなどの半導体素子とは異なり単結晶を形成させることが難しい。結晶性の良い窒化物半導体の単結晶膜を得るためには、ＭＯＣＶＤ法やＨＤＶＰＥ法などを用いサファイアやスピネル基板など上にバッファー層を介して形成させることが行われている。サファイア基板などの上に形成された窒化物半導体層を所望の大きさに切断分離することによりＬＥＤチップなど半導体素子を形成させなければならない。

【０００５】サファイアやスピネルなどに積層される窒化物半導体はヘテロエピ構造である。窒化物半導体はサファイア基板などとは格子定数不整が大きい。また、サファイア基板は六方晶系という結晶構造を有しており、その性質上へき開性を有していない。さらに、サファイア、窒化物半導体ともモース硬度がほぼ９と非常に硬い物質である。

【０００６】したがって、ダイヤモンドスクライバーで切断することは困難であった。また、ダイサーでフルカットすると、その切断面にクラック、チッピングが発生しやすく綺麗に切断できなかった。また、場合によっては基板から窒化物半導体層が部分的に剥離する場合があった。

【０００７】窒化物半導体の結晶性を損傷することなく半導体ウエハーを正確にチップ状に分離することができれば、半導体素子の電気特性や効率を向上させることができる。しかも、１枚の半導体ウエハーから多くの半導体チップを得ることができるため生産性をも向上させられる。

【０００８】そのため窒化物半導体ウエハーはダイヤモンドスクライバーやダイサーを組み合わせて所望のチップごとに分離することが行われている。チップごとの分離方法として特開平８－２７４３７１号などに記載されている。具体的一例として、図５（Ａ）から図５（Ｄ）に窒化物半導体素子の製造方法を示す。サファイア基板(501)上に窒化物半導体層(502)が形成された半導体ウエハー(500)を図５（Ａ）に示している。サファイア基板下面側から窒化物半導体層に達しない深さでダイサー（不示図）による溝部(509)を形成する工程を図５（Ｂ）に示している。溝部(509)にスクライブ・ライン(507)を形成する工程を図５（Ｃ）に示してある。スクライブ工程の後半導体ウエハー(500)をチップ状の半導体発光素子(510)に分離する分離工程を図５（Ｄ）に示してある。これにより、切断面のクラック、チッピングが発生することなく比較的綺麗に切断することができるとされている。

【０００９】

【発明が解決しようとする課題】しかしながら、半導体ウエハーの一方のみにスクライブ・ラインなどを形成させると分離時に他方の切断面にクラック、チッピングが発生しやすい傾向にある。分離された窒化物半導体素子の一表面形状は揃えることが可能であるが、窒化物半導体素子の他方の表面形状ではバラツキが発生し、半導体ウエハーにクラックやチッピングが生じやすい。したがって、半導体ウエハーを分離するときに、スクライブ・ライン形成面側から形成されていない半導体ウエハー面側への割れかたを制御し完全に窒化物半導体素子の形状を揃えて切断することは極めて難しいという問題を有する。

【００１０】他方、半導体ウエハーの両面にスクライブ・ラインを形成させ窒化物半導体ウエハーの割れ方を制御することは可能である。しかし、窒化物半導体ウエハーの両主面にスクライブ・ラインを形成するには半導体ウエハーをゴミの付着などを防止しつつ、ひっくり返し再度固定する工程が必要となり極めて量産性が悪くなる。また、サファイア基板上に形成された窒化物半導体の半導体ウエハー硬度は極めて高くダイヤモンドスクライバーのカッター刃先などの消耗、劣化が多くなり加工精度のバラツキ、刃先交換の為の製造コストが発生する。さらには、ダイヤモンドスクライバーでスクライブ・ラインを形成させると刃先の磨耗に応じてダイヤモンドスクライバーの加重を変えなければならない。また、ダイヤモンドスクライバーによりスクライブ・ラインを形成させるためにはそのダイヤモンドの刃先ごとに適した角度で接触させなければならず極めて量産性が悪いという問題を有する。

【００１１】より小さい窒化物半導体素子を正確に量産性よく形成させることが望まれる今日においては上記切断方法においては十分ではなく、より優れた窒化物半導体素子の製造方法が求められている。

【００１２】特に、窒化物半導体の結晶性を損傷することなく半導体ウエハーを正確にチップ状に分離することができれば、半導体素子の電気特性や効率を向上させることができる。しかも、１枚のウエハーから多くの窒化物半導体素子を得ることができるため生産性をも向上させられる。

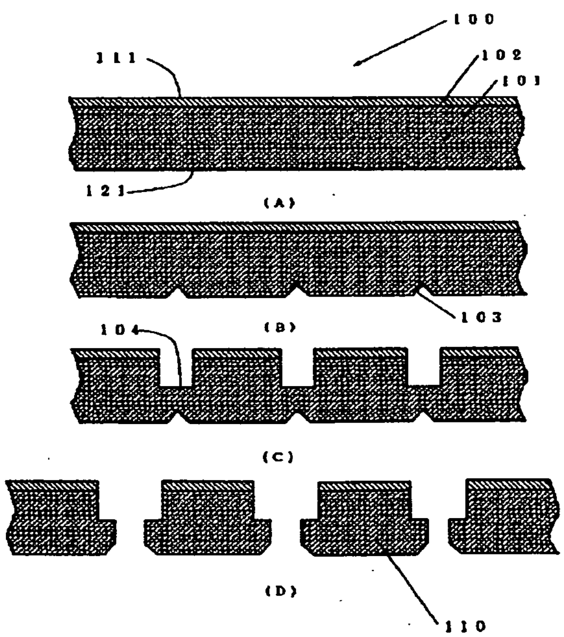
【００１３】したがって、本発明は窒化物半導体ウエハーをチップ状に分離するに際し、切断面のクラック、チッピングの発生をより少なくする。また、窒化物半導体の結晶性を損なうことなく、かつ歩留まりよく所望の形、サイズに分離された窒化物半導体素子を量産性良く形成する製造方法を提供することを目的とするものである。

【００１４】

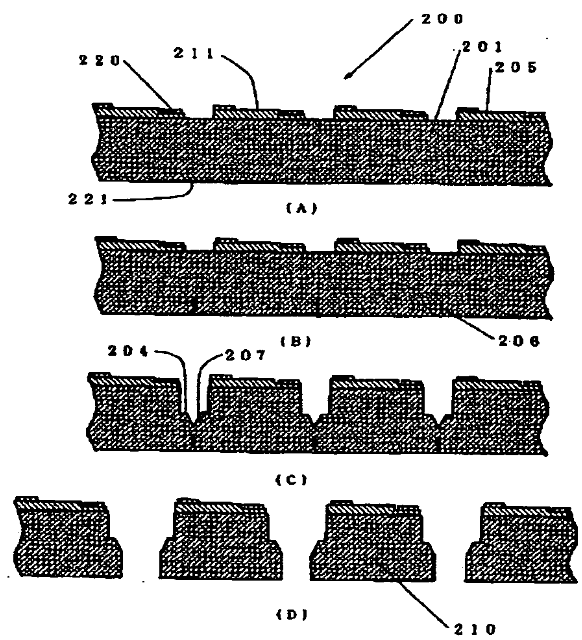
【課題を解決するための手段】本発明は、基板(101)上に窒化物半導体(102)が形成された半導体ウエハー(100)を窒化物半導体素子(110)に分割する窒化物半導体素子(110)の製造方法である。特に、半導体ウエハー(100)は第１及び第２の主面を有し第１の主面(111)側及び／又は第２の主面(121)側からレーザーを半導体ウエハー(100)を介して照射し少なくとも基板(101)の第２の主面(12

【００７１】
【図４】図４は本発明の実施例４における半導体ウエハーの分離方法を示した模式部分断面図である。
【００７２】
【図５】図５は本発明と比較のために示す窒化物半導体ウエハーの切断方法を示した模式的部分断面図である。
【００７３】
【符号の説明】
１００、２００、３００、４００・・・半導体ウエハー
１０１、２０１、３０１、４０１・・・基板
１０２、３０２・・・窒化物半導体層
１０３、４０３・・・基板表面に形成されたスクライブ・ライン
１０４、２０４・・・半導体層面よりサファイア基板に形成した溝部
２０５、４０５・・・島状窒化物半導体層
２０６・・・基板内部に形成した加工変質層によるスクライブ・ライン
２０７、３０７、４０７・・・溝部底面に形成したスクライブ・ライン
３０８・・・半導体層と基板の境界に形成したスクライブ・ライン
３０９、４０９・・・サファイア基板に形成した溝部
１１０、２１０、３１０、４１０・・・窒化物半導体素子
１１１、２１１、３１１、４１１・・・第１の主面
１２１、２２１、３２１、４２１・・・第２の主面
２２０、４２０・・・電極
５００・・・半導体ウエハー
５０１・・・基板
５０２・・・窒化物半導体層
５０７・・・溝部底面に形成したスクライブ・ライン
５０９・・・サファイア基板に形成した溝部
５１０・・・窒化物半導体素子

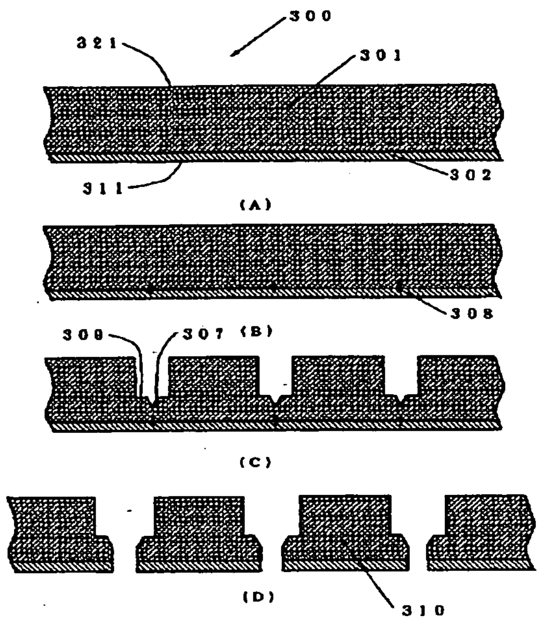
【図１】



【図２】

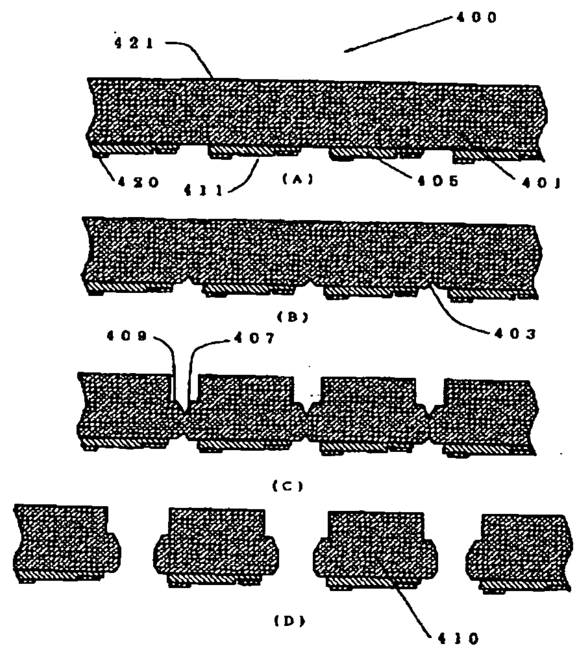


【図３】



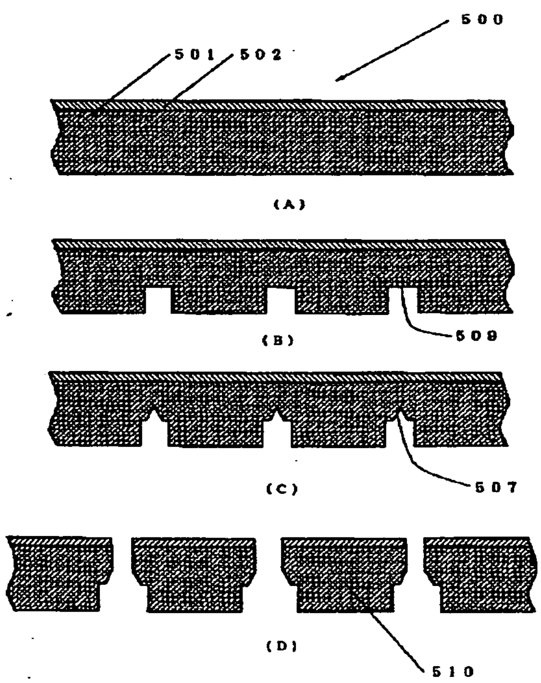
300
321
301
311
302
(A)
308
309
307
(B)
(C)
(D)
310

【図４】



400
421
420
411
(A)
405
401
(B)
403
409
407
(C)
(D)
410

【図５】



500
501
502
(A)
(B)
509
(C)
507
(D)
510